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ON THE

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ON THE

PRINCIPLES AND MANAGEMENT

OF THE

MARINE AQUARIUM.

A PAPER READ BEFORE THE

Birmingham Natural History and Microscopical Society,

AT THE MIDLAND INSTITUTE,

ON TUESDAY, 27th JANUARY, 1874,

WITH ADDITIONS,

BY

WILLIAM R. HUGHES, F.L.S.,

PRESIDENT FOR THE YEAR.

LONDON:
JOHN VAN VOORST, 1, PATERNOSTER ROW.
1875.

189. e. 115.

" In this review of the pains and pleasures of a period which stands widely apart from the ordinary routine of my existence, I have felt the joys and sorrows of years crowded into a few hours, and I have risen from this contemplation of by-gone days more and more deeply impressed with the conviction of the beneficent, calming and ennobling influences of the study of nature generally, and of the history of living beings more especially. The study of zoology, by bringing us constantly into the presence of the infinitely grand and varied problem of organisation, and by comprehending within the scope of its contemplation both animal structures and that unknown agent which we term *life*, at once stimulates our reasoning powers and elevates our moral aspirations, and thus satisfies all the requirements of our double nature. And it is no doubt owing to the fact of this science appealing simultaneously to our intellectual and moral instincts that it exerts so powerful an influence over those who devote themselves in a humble and teachable spirit to its pursuit."—*The Rambles of a Naturalist on the coasts of France, Spain, and Sicily*, by A. de Quatrefages, translated by E. C. Otté, 1857.

TO

PHILIP HENRY GOSSE, ESQ., F.R.S.

Author of *The Aquarium,*

I INSCRIBE THE RE-ISSUE OF THIS PAPER, WITH FEELINGS

OF SINCERE GRATITUDE AND RESPECT.

PREFACE.

The writer having had nearly fourteen years' experience in the management of the Marine Aquarium, hopes that this little book, which is an enlargement of the original paper read before the Society, may be found useful to amateurs and students who wish for a manual of practical instruction thereon.

Being assured that the appreciation of the Marine Aquarium as an important educational institution is steadily advancing, and feeling that any information, which from this point of view assists its progress, will be very acceptable and valuable to the public, the writer invites criticism from those who have studied the subject.

BIRMINGHAM,
March, 1875.

ON THE PRINCIPLES AND MANAGEMENT

OF THE

MARINE AQUARIUM.

I APPEAR before you as the author of a Paper this evening in compliance with the request of certain of the Members, made to me some time since by the Honorary Secretary, that I would give some information as to the management of my own Aquarium; and because it has occurred to me that any particulars on the subject of Aquaria generally may be acceptable at the present time, when public attention has been directed to the establishment of a Marine Aquarium in Birmingham, the more especially as I have, since our last *Soirée* when I had the honour to introduce the subject, met many intelligent men in the town who have said to me, "Yes! a Marine Aquarium would be a "capital thing for Birmingham, but how should you manage about the "water?" A very natural question, and one *per se* that is capable of a ready answer. Bring it by rail at the cheapest rate you can get it, as you would any other commodity that you require from a distance! But to my querists I fear this answer would by no means solve the difficulty in their minds, which is probably more deep-seated than appears on the surface—the popular notion of an Aquarium being in all probability derived from those antiquated glass vessels of globular shape and narrowed upper extremity (upon which it would be well if the Legislature imposed a heavy tax as a prevention of cruelty to animals)—in which gold and silver fish have been imprisoned, and the water has been changed at more or less irregular intervals! My present purpose is to show,—incidentally in connection with its principles and management,—what those experienced in these matters are perfectly well aware of, that the water of a well-managed Aquarium needs to be changed no more than does the soil of one's garden in which are grown vegetables and flowers. It is, however, true that there is a loss of quantity by evaporation, and also a loss of some of the chemical constituents of sea-water, on account of the extraction of calcareous matter by tubeworms, crustaceans, &c., which deposit it in constructing their coverings—as vegetables and flowers extract a certain amount of the original constituents of the soil, which may be replenished from time to time by natural or artificial means. Therefore the soil is simply a medium for the growth of plants—and the water in the Aquarium a medium for the preservation of animals.

Beyond my own circle of friends and from those not members of this Society the question may naturally arise—but what are *your* qualifications for giving an opinion on the subject of Aquaria?—the querists naturally inferring from my official position as Treasurer of your great Borough that figures and foraminifera—accounts and sea-anemones—blue books and barnacles have very few affinities in common. It might be of little interest to this meeting to tell how upwards of thirteen years ago, I first directed my attention to the subject of Marine Zoology, but to me it is a very pleasant retrospect, and the names of kind friends to whom I am indebted for early instruction, such as Dr. Wade, Mr. W. Mattieu Williams, formerly of this Institute, Mr. Joseph Bragg, and others, occur to my mind with grateful remembrance. Subsequently, when I had outstepped their teachings—succeeded those of Mr. P. H. Gosse, from whom personally and through whose writings I have derived the most valuable information and benefit in many ways, similarly, from Dr. Spencer Cobbold, and from Mr. W. A. Lloyd, of the Crystal Palace, Hamburgh and other Aquaria, whose great knowledge and experience have always been at my service during a period of twelve years, whenever I have sought his opinion. Throughout that time I have maintained in perfect health marine animals of great variety and beauty—some of excessive rarity—for example the beautiful Vestlet *Cerianthus Lloydii*, (*Edwardsia vestita*) which figures life-like—thanks to the gifted pencil of my friend Mr. G. Sherriff Tye in the 1st part of the Transactions of our Society, and which is now I believe nearly extinct on the British shores. Regarding that beautiful order of Zoophytes the *Actinoida* (or sea-anemones) I was quite surprised on looking over the Crystal Palace Hand Book of my friend Mr. Lloyd to find that at one time or other I had possessed twenty-four of the species (thirty) enumerated therein, and that, moreover, I had been fortunate in possessing three species not now in that Collection. It is not too much to say that I have exhibited to this Society at various times during its existence—and that of its parent—" the Birmingham Natural History Association "—a greater number of rare and beautiful marine animals than have been shown and described at any other inland Society, and I would fain hope with some little benefit to science.

I do not mention this ostentatiously, but simply to give a practical illustration of what can be done by the Marine Aquarium even in a small way. The Aquarium has really an advantage over those beautiful little fairy-like rock pools at the sea coast—you can group together animals of different localities which never can be associated together naturally—and you can examine them at your leisure in your own room, and I venture to say that neither you nor your friends will ever tire of the examination. To me during these years, the Marine Aquarium has been a subject of intense interest, and an intellectual recreation of the greatest relief after official work, always of a laborious and responsible character.

The history of Marine Aquaria is interesting, and will repay perusal by all who feel inclined to consult Mr. Gosse's exquisite Book—"The Aquarium," or Mr. Lloyd's "Hand-Book to the Crystal Palace Aquarium" —a wonderful sixpennyworth of information that ought to be in the hands of every marine Naturalist. To our great townsman, the late Dr. Joseph Priestley, for his grand discovery of the mutual dependence of plants and animals on each other, must be awarded the honour of its discovery. No matter in what Aquaria—fresh-water or marine—public or private—large or small—these principles govern them. The mode in which they are applied may vary greatly, but the effect aimed at is the same. The introduction of the Marine Aquarium as an object of public interest is however mainly, if not entirely, due to the delightful books of Mr. Gosse—nearly a quarter of a century ago—which contain illustrations by his pencil so novel, beautiful, and truthful, besides being coloured after nature, that they have marked a new era in Zoological literature.

THE MARINE AQUARIUM—Mr. Gosse's definition of it.

In his "Naturalist's Rambles on the Devonshire coast," Mr. Gosse states that for several years past he had been paying attention to our native *Rotifera*, "and in the course of this study had kept fresh water "in glass vases unchanged from year to year, yet perfectly pure and "sweet and fit for the support of animal life, by means of the aquatic "plants, such as *Vallisneria*, &c., which were growing in it. Not "only did the Infusoria and Rotifera breed and multiply in successive generations in these unchanged vessels, but *Entomostraca*, "*Planariæ*, *Naides*, and other Annelides and *Hydræ* continued their "respective races; and the young of our river fishes were able to "maintain life for some weeks in an apparently healthy state, though "(perhaps from causes unconnected with the purity of the water) I "was not able to preserve these long."

"The possibility of similar results being obtained with sea-water "had suggested itself to my mind, and the subject of growing the "marine *Algæ* had become a favourite musing, though my residence in "London precluded any opportunity of carrying out my project. My "notion was that as plants in a healthy state are known to give out "oxygen under the stimulus of light, and to assimilate carbon, and "animals on the other hand consume oxygen and throw off carbonic "acid, the balance between the two might be ascertained by experiment, and thus the great circular course of nature, the mutual "dependence of organic life, be imitated on a small scale."*

Mr. Gosse then describes at length his most interesting and successful experiments with marine animals and plants, based on "the

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* "A Naturalist's Rambles on the Devonshire Coast," by P. H. Gosse, A.L.S., &c., London 1853, pp. 228-9.

"important anticipation that by this plan great facilities would be "afforded for the study of marine animals, under circumstances not "widely diverse from those of nature," and it is a very remarkable coincidence, that experiments exactly parallel to his, and founded on the same principles, were simultaneously prosecuted with the same results, by Mr. Robert Warington, of Apothecaries' Hall, London, (since deceased), who preceded Mr. Gosse in instituting these experiments.

Soon after this period (1852) the Marine Aquarium became a fashionable amusement which reached a fever of excitement in 1860—something like potichomanie or crochetwork—and appears, on Mr. Lloyd's authority, to have nearly died out in 1862, or to have been confined to a few enthusiastic amateurs—since which period, however, public Aquaria have steadily grown into favour.

To help us to arrive at a knowledge of the principles of the Aquarium we must first ascertain what it is. To Mr. Gosse we are indebted for the name *Aquarium*—as applied to a receptacle for plants and animals mutually balancing each other—and he discusses in his delightful book with that title, its propriety as such, being a word " easily pronounced and easily remembered, significant, and expressive." Dr. Carpenter, and others use the term *Vivarium*—to which Mr. Gosse objects, as it lacks distinctness of meaning, literally being an enclosure in which living animals are kept, such as a park, a rabbit warren, or a fish pond, in which sense it was used by the Ancients. Some authors have lengthened the term to *Aqua-vivarium*, to which Mr. Gosse also objects on account of its length and uncouthness. The word *Aquarium* is, therefore, in use popularly as signifying a collection of aquatic animals maintained in health by plants, or by artificial means supplying their place, "distinguishing it as a Fresh-water Aquarium if the contents "be fluviatile, or a Marine Aquarium if it be such as I have made the "subject of the present volume."*

I venture to suggest the word *Aquariist* as the most convenient, if not the most correct, as applicable to one skilled in the management of the Aquarium. I do so, because the word *Aquariologist* is too long, and the word *Aquarian* is too indefinite, it has been, I believe, used in three senses; 1. By my friend Mr. Newman, to a person who works at, or keeps an Aquarium; 2. By the Americans to a "water drinker," or "teetotaller;" and 3. By the early Christians, who used water instead of wine in the celebration of the Eucharist. Mr. Newman's definition, however, has priority to recommend its adoption if desirable.

Mr. Lloyd, in his book before referred to, which contains the most recent results of his large practical experience, describes the Aquarium as "an arrangement for the maintenance of living animals, "under the following three conditions," viz.:—

"1st. The water must not be changed, though it may receive "addition from time to time of whatever it may lose, as, for instance, "in fresh water by evaporation, or in such solid matters as are taken "from it in the course of the formation of the shells and other hard "parts of creatures existing in it.

"2nd. The water must be kept not only in a pure and respirable "condition by its absorption of atmospheric air at its surface, which

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* "The Aquarium: an unveiling of the wonders of the deep sea," by P. H. Gosse, F.R.S. Second Edition. London, 1856, p. 251.

" absorption may or may not be increased by putting the water in " motion in any convenient manner, but this purity must be assisted "by the presence of vegetation growing in it, and tending to decompose " the poisonous carbonic acid gas evolved from the animals, such vegetation taking up the carbon of the gas into its own substance, and " liberating the resulting oxygen for the use of the creatures.

" 3rd. The Animals must not be lung-breathers, that is to say, they " must be either such as the sea-anemones and corals and some others " which have the function of respiration diffused over their entire " bodies; or, be such as the creatures above them (up to and ending " with fishes), which are provided with gills during their whole period " of existence. As lunged animals do not require the purifying processes just alluded to, an Aquarium is not for their use, and they are " therefore excluded from it; and this exclusion applies even to such "aquatic animals as water lizards, frogs, and salamanders in their adult " states."*

Exception may be taken to the third of Mr. Lloyd's propositions because the admission or rejection of lung-breathers in no way interferes with the balance of the Aquarium, and it is, therefore, a mere matter of opinion. The presence of an aquatic mammal in an Aquarium sufficiently large for its accommodation would, it seems to me, be somewhat analogous to the position of a ship sailing over the sea. The motion of the ship would, to a feeble extent, aërate the water by disturbance of its surface—the mammal, by its swimming in the Tank, would mechanically contribute to the same effect in, of course, a greater degree, but so far as chemical action is concerned, except as to the excreta which would probably be insignificant in the large mass of water required for its accommodation, the mammal could not have an appreciable influence either in maintaining or disturbing the balance. Those who saw the first porpoise in the Brighton Aquarium will doubtless remember, that in the large Tank in which it was confined there were a number of conger eels, which of course supplied the "animal balance," and therefore the presence of the mammal was not essential to, and in no perceptible way interfered with such balance—and moreover, there was ample space for its accommodation without interfering in any way with the congers, which generally rested at the bottom of the Tank. Bearing, therefore, these points in mind, and even admitting that an Aquarium is, according to Mr. Lloyd's third proposition, a *habitat* solely for marine or fresh-water animals not being lung breathers—and supposing it is determined to keep lung breathers as well—such as porpoises, dolphins, etc.—surely they must be maintained in *water which for all practical purposes will be an Aquarium*, although not strictly answering to its original but perhaps somewhat restricted name, and for reasons already stated it is not desirable to change that name—rather then let it be more comprehensive and admit (where practicable) animals of higher organisation, such as those referred to.

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* "Official Hand Book to the Marine Aquarium of the Crystal Palace Aquarium Company (Limited)," by W. A. Lloyd. Fourth Edition, 1873, pp. 7, 8.

Writing on this subject, and on others in connection with the Marine Aquarium—in the progress of which he has always taken the deepest interest—in the *Zoologist* for 1873, Mr. Newman says; "A "porpoise or dolphin is as legitimate an object for the Aquarium as a

" dog-fish or a skate;—I would even introduce a spermaceti whale " did not his magnitude and muscular powers suggest certain difficulties " both to his transit and to his captivity." *

I, therefore, in common with Mr. Newman, agree to differ with our friend, and consider the managers of the Brighton or any other public Aquarium are, without involving the sacrifice of the name Aquarium, or violating the law that governs it, perfectly justified in introducing a porpoise, or other aquatic mammal, if they can secure and maintain it alive, and exhibit it to the public as an object of interest, or, what is more important, derive from it information on any point of scientific value.

How and by what means the other important propositions involving the perpetual chain of evolution of one gas by one series of life, and its absorption under modified conditions by another series, it in its turn giving off in exchange the life constituents necessary for the first, and thus constituting the balancing principle of the Marine Aquarium, are to be successfully carried out—I will try and explain, —very briefly on this occasion, and so far as our present knowledge permits—for the limits of a Paper of this description will not allow of very elaborate detail.

I venture to define an Aquarium in its liberal sense, as being a vessel of some kind for marine or fresh-water animals to live and move in, under conditions where a sufficient amount of oxygen is supplied naturally or artificially for the existence of such animals, whether it be in the case of the simpler forms of life, such as sea-anemones which

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* *The Zoologist*, conducted by Edward Newman, F.L.S., F.Z.S., Second Series, September 1873, p. 3,663.

respire over the whole surface of their bodies, or animals of higher organisation where the organs of respiration are differentiated, as fishes, which respire by means of gills; or mammals which breathe by means of lungs; such mammals absolutely requiring water as a means to move in, and coming to its surface to obtain oxygen from the surrounding atmosphere necessary to breathe in.

The three cardinal subjects to bear in mind in their order of importance, influencing these conditions, are *light*, *aëration* (which implies *circulation*), and *temperature.*

The recent researches in deep-sea dredging although they have cleared up many most important points as to the geographical distribution of marine animals—pressure—currents—temperature, etc., of the sea, and have inaugurated the wonderful doctrine of "the continuity of the chalk," have left us still in much obscurity about that mighty question *light*, and its effects on marine life. The latest accounts record instances of animals composed almost wholly of eyes—while others indicate the total absence of such organs in other animals! Phosphorescence may at great depths compensate the absence of light, for we read* that at a depth of about 600 fathoms—off the South East coast of Ireland—"Many of the Animals were most brilliantly "phosphorescent, and we were afterwards even more struck by this "phenomenon in our Northern cruise. In some places nearly every-"thing brought up seemed to emit light, and the mud itself was "perfectly full of luminous specks. The Alcyonarians, the brittle-Stars, "and some Annelids were the most brilliant. The *Pennatulæ*, the "*Virgulariæ*, and the *Gorgoniæ* shone with a lambent white light,

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* "The Depths of the Sea," by Professor Wyville Thomson, F.R.S., 1873, p. 98.

" so bright that it showed quite distinctly the hour on a watch; whilst " the light from *Ophiacantha spinulosa* was of a brilliant green, " coruscating from the centre of the disk, now along one arm, now " along another, and sometimes vividly illuminating the whole outline " of the star-fish."

It is certain that *light* is the primary question to be considered in relation to Aquaria. The presence of it in an uninterrupted volume combined with a high rate of temperature, may in a few days convert an Aquarium which was in an efficient condition of health and beauty of the inhabitants, into a decomposing mass. It must be borne in mind, however, that light alone without a high temperature cannot cause decomposition in an Aquarium. Excessive light causes an excessive development of Algæ spores, which make sea-water and even fresh-water opaquely green, but that does not interfere with the health of the animals. When the temperature is above 40° Far., light must be admitted sparingly, and adjusted as to quantity and quality. The direct rays of the sun should never be allowed to converge on an Aquarium, especially if they proceed from the direction of the south, or west, or south-west.

Figure 1 represents a glass Tank transparent on all sides—placed in a conservatory—with the rays of the sun in this objectionable manner. The situation is objectionable, the light and heat are objectionable, the vessel is objectionable. They illustrate the extremes to be avoided—because in addition to the great heat directed upon the Tank—the growth of vegetation will be too excessive—no part of the Tank will be free from its development. It is a false balance.

Figure 2 represents a lateral form of illumination in a far less objectionable manner for transparent, and still less for opaque Tanks, the straight lines in the figure representing the passage of the rays of light, which in the former case would pass through, as at the dotted lines —and although the light in these instances may be right from a point in which the north and east rays predominate—the form of the vessel is bad, especially in the transparent one, where the rays pass through it, as it offers too large a surface for the reception of light, and the consequent excessive growth of vegetation is promoted.

Figure 3 represents what my experience has proved to be the most effective, viz.: the slope back dark-chamber Tank, which I have had in constant use upwards of twelve years, invented, I believe, by Mr. Edward Edwards, late of Menai Straits, but now of Chester, (whose beautiful, and successfully managed Aquaria you will remember I had the pleasure of describing to this Society in the Autumn of 1868) and which was manufactured by Mr. Lloyd. In it there is a minimum space for the reception of the rays of light. It consists of slate and glass. The dimensions are about 22 inches long, by 18 inches wide, and 9 inches high. Its capacity is about twelve gallons. Three sides are opaque—the fourth (of glass) transparent. It is, therefore, viewed horizontally from the room in which it is placed, which is its best aspect for the examination of the inhabitants, but of course it permits of vertical observation in addition. The dark-chamber is intended to hinder the excessive formation of the spores mentioned at page 20, but it does not prevent the formation of vegetation on the rockwork, etc. It contains a shelving platform, on which are piled masses of rockwork up to the top of the inclined surface, and thus the animals can select depths of water most agreeable to them. The dark-chamber at the back excludes the mass of water therein from the light, thus keeping it cool and free from vegetation, but there is a free circulation between this and the main body of water in the Tank, artificially assisted as hereafter described. Moreover, the rays of light coming from a north-easterly point, (which is the best aspect for an Aquarium, and which is the position in which mine is placed)—in a slanting direction parallel with the platform, enter the water at *its surface only.* Any other mode of illumination is bad—and experience during twelve years has demonstrated to me, in maintaining rare and delicate animals, that this form of Aquarium for private purposes is the best of all. This arrangement is not necessary in public or other Aquaria provided with streams, because separate reservoirs, such as that which the Crystal Palace possesses, form in themselves the dark chambers. Any Aquarium may be exposed to great light and may be unprovided with an annexed dark chamber, and yet it may act well, if it has a separated reservoir underground, of four or five times the capacity of the Aquarium, with which it is in constant and sufficient communication.

As to *aëration*, it follows—the larger the surface of water exposed to the atmosphere the larger amount of oxygen will be absorbed. Mr. Lloyd justly says that—"the value of water for Aquarium purposes does not within certain limits depend so much upon the bulk "of it as upon the advantageous distribution of that bulk over large "spaces." Observe the following illustrations :—

Figures 4 and 5 represent two Tanks or vessels of equal capacity —the contents of each being 1,000 cubic inches. The depth to the water line as shown by the dotted lines respectively, is in No. 5—5 inches; and in No. 4—20 inches. The surface water in contact with the atmosphere is in No. 5, 200 square inches, and in No. 4, only 50 square inches. Therefore the absorption of air is in No. 5 four times as much as in No. 4. Again, if the surface of No. 5 is smartly agitated for a few minutes, the whole column of water is exchanged—but the time necessary for this exchange would in No. 4 be quadrupled. Therefore No. 5 would accommodate twenty animals in health, against a fourth of that number in No. 4. These figures are copied from Mr. Lloyd's first book, published in 1858,* and have been lithographed for me by Mr. G. Sherriff Tye, to whom I record my obligation, as also for the other five original drawings.

The Tank which I have mentioned, permits in a greater degree this mode of aëration than any other. With healthy plants growing in it, and balancing the animal life it needs but a minimum of attention. All that is required being the breaking of the surface, so as to exchange the water in contact with the atmosphere, and prevent the accumulation of a film of dust. This "breaking" is effected by means of a pair of boxwood forceps about seventeen inches long, as at Fig. 7. The forceps are held firmly and passed rapidly through the water for a few minutes until the whole mass has been disturbed, and bubble-like froth in which atmospheric air is entangled appears on the surface. This mode is preferable to syringing or such like operations. These latter disturb the stratum of shingle at the bottom of the Tank, and do not effect an equal distribution of the air introduced; besides, the interior of a syringe soon becomes objectionable in odour, and unfit for use. My observations under this head, will explain the reasons expressed in an earlier part of my Paper against the fish-globe shape for Aquaria, where the surface is narrowed and contact with the atmosphere lessened. For those who do not care to invest in a Tank, a nice little Aquarium, Fig. 6, can be had for a few shillings. Obtain a confectioner's cake-glass of about 13 or 14 inches diameter, and 6 or 7 high—of flint glass free from flaws, have a pedestal stand turned for it of some hard wood with an aperture for the knob to fit in; and, although you will have some trouble in the adjustment of the light, still with care you may obtain some very good effects, and maintain for a long time many marine animals of the radiate type and even small fishes in excellent health. It cannot, however, be considered a model Aquarium.

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* "A List of whatever relates to Aquaria," by W. A. Lloyd, London, 1858, p. 130, and "Supplement to the same, 1860."

Paint is excessively injurious to the contents of an Aquarium, and wherever painting is going on in the house, the Aquarium should be removed to another room away from its influence. Miss Stephens, of Bridport, who has had considerable experience in the management of Aquaria during many years, informs me that exposure to the influence of an atmosphere impregnated with the smell of paint entirely destroyed the inmates of an Aquarium, and a similar case occurred within my own experience in which a rare fish died from the effects of varnish used after painting in the apartment in which the Aquarium was placed; the volatile constituent of the varnish condensed as a scum on the surface of the water, and thus interfering with proper aëration produced the effect described.

If the Fishes seek the surface of the Aquarium constantly—or refuse food at the usual time—if the anemones reject food—or protrude the walls of the alimentary cavity—or abnormally elongate the column—or detach the base from the rockwork and lie about loosely—these are bad signs, indicating local decomposition, overcrowding, or the effects of insufficient aëration, and the evil must be at once sought out and remedied.

The common anemone of the coasts (*Actinia mesembryanthemum*) is, I believe, the best indicator of the healthy state of a Tank, as it refuses to expand when the water is in an insufficiently aërated condition, or too dense from an insufficient supply of fresh water.

The higher the organisation of the animal the greater is its breathing capacity—therefore in public Aquaria, where large fishes are maintained, a free circulation of water through the Tanks, seems to me in the absence of a full complement of plants a necessity to obtain perfect aëration, and without it it appears to me, to say the least, doubtful that such Aquaria can be conducted with that economy and successful result which characterise the circulating system.

Various mechanical appliances have at times been suggested for aërating the water in Aquaria—notably that of Mr. Hurwood, of Ipswich, in 1859, which was "an arrangement whereby the pressure of "a stream of fresh-water, such as exists in the pipes of waterworks in "towns, or such as can be got from a high cistern already existing in a "dwelling-house, may be employed to compress air, which compressed "air in turn forces a current of sea-water into an Aquarium.—This "arrangement was adopted in several private Aquaria in England, "but afterwards on a much larger scale in the first public Aquarium "erected in Paris, in the Acclimatation Garden, in 1859. This Aquarium

" was very successful, the sea-water not being changed once during its " thirteen years of existence." * The late Dr. Ball, of Dublin, also invented "a method of keeping sea-water in occasional motion by "passing bubbles of air through it with a pair of bellows," and it was proposed that the apparatus should be worked by visitors to the public Aquarium of that city—but, I believe, it is not recorded as to whether the invention was successful in its results. Some years ago, I availed myself for a short time of a contrivance for aërating the water, by suspending over the Aquarium two or three feet high, a bell-glass perforated at the bottom. This glass was filled once or so in a day, and the water allowed to filter through a sponge, and drop into the Tank below. On the whole I found the effect incommensurate with the trouble occasioned, and I discontinued the proceeding. Where practicable, Otto and Langen's gas engine appears to be an exceedingly effective, economic and compact motive power for providing continuous circulation. The magnificent circulating system in use at the Crystal Palace Aquarium will be briefly referred to hereafter.

Tides, winds, storms, plants, all contribute to the aëration of the sea, and all our contrivances are only endeavours to imitate the effect of the operations of these agencies.

As to *temperature*—this is a very important subject in connection with Marine Aquaria—apprehended more clearly perhaps when it is known that the temperature of our Seas within the depths from which we obtain most of the animals adapted to exist in Aquaria, only exhibits a range of about 25 degrees, between 40° and 65° Fahrenheit, whereas our atmospheric temperature varies enormously. I am in-

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*** Official Hand Book to the Marine Aquarium of the Crystal Palace, &c., page 20.**

formed that in Britain the lowest recorded temperature in air in the shade is —7° Fahrenheit, and the highest in air in the shade is 93° Fahrenheit—or a range of 100 degrees. Consequently it is most desirable that the former range (40° to 65°) shall be maintained. The water in the Aquarium should always be cold to the hand, let the temperature of the atmosphere be whatever it may. Placed in a north-easterly, or north, or east position, as I have stated previously, and in a room well ventilated, and that has ordinarily in cold months a fire burning in it, there is little to be feared. Extreme cold, although sometimes fatal to animals of the radiate type, is not accompanied by rapid decomposition, on account of the low temperature prevailing, and it may be modified by placing over the Tank at night a newspaper, or covering of some non-conducting material. At other times the Tank should not be covered, but exposed to the free play of the atmosphere. The danger is greatest from an opposite cause, arising from rapid decomposition, when almost tropical heat suddenly sets in during the summer months. At this time the patience of the Aquariist will be tried—but by frequent ventilation of the apartment—by shutting off light by means of a Venetian or other blind—by the introduction of a piece of ice once a day, and above all means by not overcrowding the Aquarium with animals, one may pull through even the "dog days" with success. It is desirable here to mention that it is a great mistake when a Tank is going on well to add to its stock. Refuse your friends' present courteously but firmly, and do not be tempted under any circumstances to accept the responsibility of a "white elephant."

Respecting the management of the Marine Aquarium, which is purely practical—the good old proverb, "cleanliness is next to godliness," is eminently applicable. If we regard the Aquarium in the light of a Sanitorium or House of Convalesence, which is a convenient mode of fixing upon one's mind the necessity for the greatest amount of purification naturally and artificially to be always carried on, we shall instinctively manage it with this object in view, never introducing anything impure, or in even a state of *semi* decomposition, removing such if discovered, and being careful to aërate the water and purify whatever was near the decomposing substance. Do not, however, think that this is a tedious and harassing process. It is nothing of the kind. Ten minutes a day—five at night and five in the morning—are quite sufficient for all the *necessary* work needed. Mr. Lloyd very justly says in his Hand Book before referred to—* "that the reason why Aquaria in private houses have met with such "small success may be found in the natural difficulty of the whole "thing; in the general want of a knowledge of Zoology among those "attempting it; and in the difficulty of producing an at once "sufficiently comprehensive and practical manual of instructions on "the subject. General laws can only in such cases be stated, "as it is not possible to give any definite rules, applicable under all "circumstances, respecting the kind, sizes, and number of animals "which may be permanently kept in a given quantity of water, inasmuch as the capability of the water for maintaining the animals in a "private house (and even in a building specially made for Aquarium "purposes), is liable to continual change from various circumstances, "among which temperature is a principal one, and regulation of light

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* pp. 12—13.

" is another. Such capability is also greatly affected by the propor-
" tions of the vessel containing the water, for if the fluid is spread out
" in shallow masses, its absorption of air by mere surface contact with
" it, and its consequent good condition is much greater than when it is
" piled up (so to speak) in tall masses with small surface area."

Undoubtedly a stream of water, intermittent or continuous, accompanied by means for introducing an abundant supply of air to the Aquarium are best adapted to produce the most successful results—if one considers for a moment the general character of the inhabitants of a stagnant pond in which live eels, tench, and carp, and that of a clear torrent-like river where live trout, salmon, and grayling, one gets a tolerably good notion of the superior effects of this mode of oxygenation. But this is scarcely practicable without much expense in a private Aquarium, although to my mind, as already stated, most necessary in public Aquaria. By a private Aquarium I mean one maintained in an ordinary dwelling house. Nevertheless, by the careful adjustment of the balance of the relations of animals and plants—by agitation of the surface for a few minutes at night and morning, so as to allow no film of dust to accumulate or interfere with the free play of air over the surface, we may get in some degree a substitute—though animals of high organisation as fishes cannot be maintained so successfully as in public Aquaria. On the other hand, animals lower in the series of classification, such as sea-anemones and other radiates and crustaceans may be maintained for many years. Indeed, there seems no limit to the life of some of them. The celebrated *Actinia* (a variety of *Actinia mesembryanthemum*, I believe) once the property of Sir J. G. Dalyell is now stated to be in its forty-fifth year of captivity in Edinburgh, has given birth to over a thousand young ones, and shows no signs of getting old !

I propose to deal with each portion of the Aquarium establishment and management separately.

Assuming that a suitable Tank has been selected, and that the errors alluded to in the former part of my paper have been avoided, we first consider the *rockwork.* Experience has demonstrated that for such purpose nothing is so suitable as *Mica schist,* its compact non-friable character offering a favourable *nidus* for the growth of vegetation. Moreover, its dark green hue has an agreeable effect under water, and exhibits the colours of sea-anemones, tube-worms, and fishes to advantage. Animals readily adhere to it, and I have in my Tank instances of a tube-worm (*Serpula triquetra*) two inches in length, that have developed upon it from germs contained in the sea-water. The mica should be of picturesque fracture when broken up, and should first be cleansed in fresh-water of impurities, and cemented on to the sides and back of the Tank, with none but the best Portland cement, finely sifted. After it has well set, fresh river or rain water should be introduced and allowed to remain, until all impurities and opacity from lime and other causes have subsided. After this, it should be rinsed over with sea-water before the stock of sea-water is introduced. The mode of displaying the rockwork must be left to the taste of the Aquariist. I would, however, recommend the avoidance of too many deep crevices, wherein animals may lurk and die unsuspected.

Next comes the *shingle.* As a relief to the dark green of the rockwork, and as acceptable for animals, such as the *Echinus* (Sea-urchin) to burrow in, nothing is better than the finely-ground masses of flint about the size of large peas, found at Shanklin, and on some other shores of the Isle of Wight and Southern Coast,—its pale brown or buff colour is very suitable as not militating against the colours of the inhabitants of the Tank. Sand is not recommended. But few Marine animals suitable to be kept in private Aquaria are found burrowing in sand. Moreover, it is apt to get covered with a filmy mass of vegetation, very difficult to dislodge, and the removal of the sand from a Tank when requiring to be cleansed is a troublesome process. Sand is chiefly objectionable in currentless Aquaria, because it lies close, and hinders oxygenated water from circulating among it, whereas shingle has interstices admitting water. Before any shingle is introduced, it should be carefully cleansed of all shore impurities, and this is best effected by washing it in a vessel such as a domestic colander, free from any particle of grease, placed in a tub, under a water tap, when all impurities will float away over the surface. Like the rockwork it should be rinsed in pure sea-water, before being placed at the bottom of the Tank, which it may cover to a depth of two or three inches.

The *water*. If possible all sea-water for Aquaria should be procured during the winter months, as at this period it is freer from germs of life, both animal and vegetable, and absorbs a greater quantity of oxygen at the surface than at other times. If taken in the hot summer months when *Medusæ* and *Noctilucæ* are floating about towards the surface, decomposition is often a result which may cause temporary inconvenience. If required for *immediate* use, it should be taken when the tide is coming in—a mile out in the open sea, in the morning if possible, and care should be had that the vessel (such as a Bristol stone jar, or glass) in which it is conveyed is perfectly clean, and that even the cork is a new one. A bad cork has often spoiled a bottle of wine —much less has spoiled a bottle of sea-water ! No sea-water should be taken along shore from such places as Liverpool, Rhyl, &c., where rivers flow and dilute the standard quality, but the preference should be given to Weymouth, Torquay, Tenby, &c. It should be of high specific gravity, so that one gets the largest amount of saline constituents for the smallest sum of money. The water should be kept securely corked in a cool dark place, and when wanted, carefully syphoned into the tank, so that no sediment which may exist may be introduced with it. By all means keep in reserve (according to the size of your Aquarium) two or three good-sized jars of pure sea-water. It will be found useful when specimens are received, and have to be temporarily accommodated before being finally located in your Tank. All Aquariists should have a store of sea-water under all circumstances —" Old store, no sore."

The standard of the water must be maintained. Its specific gravity is about 1,026° at 60° Fahrenheit. Sea-water is less dense at a higher than a lower temperature. Evaporation goes on constantly, but this can be supplied by the introduction of distilled, or pump, or river water. I give the preference to distilled water, as it is freer from germs that may develop injuriously from river or pump water. The fresh-water should not be introduced too rapidly, but a little sea-water should first be taken out—a quart or so—and mixed with an equal quantity of fresh-water, and this should be gradually introduced and well agitated with the mass of water in the Aquarium so as to uniformly dilute it. Any deviation in the standard may be observed by a hydrometer, or by two small glass balls (of different colours) acting in concert—one floating at top, and the other remaining at the bottom of the water—when their conditions will vary with the strength of the sea-water—or what is as good as anything by "rule of thumb" mark on the Tank the normal height of the water, which should be correct at introduction, and keep it to the standard as before stated.

There is as a rule more danger to be feared from sea-water becoming *too salt* by evaporation, than by the accidental introduction of *too much fresh-water.* In the former case you have a brine or pickle, in the latter a dilution that will in time right itself.

A large public Aquarium or a small one if there are corals, or echinoderms, or crustaceans, or fishes, may require to be occasionally supplied with carbonate of lime, to compensate the quantity abstracted from the water by animals of these classes—personally, however, I have never had occasion to use it.

If properly aërated, the stock of sea-water never need be changed; the greater part of that which is now in my Tank has been unchanged (except to compensate loss) for many years—probably seven or more.

In a private Aquarium there is a certain loss caused by the slopping over of the water, and by periodical cleansing and other causes, small but appreciable, which must be supplied from the stock-bottle. In other respects there is no loss—for you may almost entirely evaporate the fluid from a given quantity of sea-water, leaving scarcely anything but its saline constituents, and again return it to its normal state by the introduction of fresh-water.

If from any causes sea-water becomes putrid, exposure of it to the oxygenating effects of the atmosphere, in shallow vessels, and occasionally breaking the surface as previously directed, will soon restore it to its original condition.

I have found that if at the bottom of the Tank there is an accumulation of sedimentary matter it is a good plan to draw off several gallons of the water with a syphon (a few feet of ¾-inch India-rubber tubing) from the bottom, and allow it to settle in separate vessels for a few hours, and then return it carefully to the Tank again. A glass dipping-tube about ten inches long by a quarter of an inch diameter is very useful for the removal of small decomposing substances.

Much has been said about artificial sea-water, but my experience is not very favourable to it—I found it crude and harsh in its effects on the anemones, they refused to expand, and shrank up and died. Should however anyone desire to make a trial of it I append Mr. Gosse's formula.* His experiments were highly successful, but this kind of water does not, so far as I know—except at Hanover and Berlin—appear to have been adopted in any public Aquarium, nor is it much favoured by amateurs, but my friend Mr. Wright Wilson reports very satisfactorily on it, and uses none other. I have been informed that if kept in a cool place for some months and the constituents allowed to blend well together, on exposure to the air the ordinary conferva found in a Marine Aquarium will develop in artificial sea-water. As the natural element can readily be obtained

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* Common table salt - - - -	3½ ounces	Avordupois.
Epsom salts - - - - - -	¼ ounce	
Chloride of magnesium - - -	200 grains	Troy
Chloride of potassium - - -	40 grains	

to which must be added a little less than one gallon of distilled water, so that a specific gravity bubble 1,026° will just sink in it. "*The Aquarium,*" p. 264.

from the coast at a few pence per gallon, I prefer it, rather than incur risk and disappointment. Artificial sea-water, however, needs trial on a large scale in England.

The various accessories of the Aquarium being supplied, now comes the important question of *vegetation.*

My experience on this head has demonstrated that if the Tank is established in the *autumn,* and a few pieces of rock introduced on which are naturally growing fronds of the sea-lettuce (*Ulva latissima*), Spores will be given off the old plants, which finding a favourable nidus in the Mica, will develop in the early spring months into healthy and vigorous vegetation, and will continue until autumn again. As soon as the young plants exhibit signs of development the old ones must be removed. It is not possible to describe the beauty of this vegetation. Even without animals (if it could exist) it would be worth maintaining in an Aquarium. Of brilliant grass-green colour, and of the richest spring tinge, the young *Algæ* appear like broad short blades of young wheat plants, gently waving sometimes with the agitation of the sea-water, and seeming, when undisturbed, like a bank of lovely green moss. From this under the stimulus of the early morning sun during a brief period, globules of oxygen (like silver) rise to the surface, and disperse in myriads. It is a truly beautiful sight—one of the most interesting I have ever witnessed in connection with Aquaria. I have known fronds of between two and three inches in length develop in this way. Now, if fishes are maintained in the Tank this vegetation is highly serviceable as food for them. I have seen my fishes,—grey mullet and wrasse,—bobbing at the vegetation for half an hour together, and I have seen the blennies tugging at it, as a bird does at a worm when making its escape into the ground. There is another great advantage connected with this form of growth, it neither attacks the slate sides of the Tank, nor the glass, nor the shingle—their smooth surfaces probably presenting no nidus or resting place for the spores.

I believe it is here for the first time demonstrated, the great advantages arising from the introduction of *Ulva* loaded with spores at this particular time of the year, when the surfaces of the rockwork are absolutely free from any other form of vegetation, and where other plants are not present to lead to a "struggle for existence"—three most important points. Any difficulty likely to occur from excessive growth, and consequent decay of this form of vegetation in the autumn, may be removed by the annual cleansing hereafter referred to.

From the repeated success of the experiment, I do not doubt that other *Algæ*, both the *Chlorospermeæ* and the *Rhodospermeæ*, may be cultivated in a similar manner, if regard be had to the points I have urged, and to the proper adjustment of light. My object in growing the young *Ulva* was not what my friend Mr. Newman pleasantly calls "the crotchet of planting the Aquarium as a lettuce garden," nor so much for purposes of aëration, but to afford a healthy vegetable diet for my fishes, and their growth and vigour are proofs of its successful effects on them. I feel very strongly on this point, and consider that no Aquarium can be complete without vegetation as a source of food for the inhabitants, irrespective altogether of its value as a means of aëration. If we consider the sea as a gigantic natural Aquarium of absolute perfection as to the balance of mutual relations, the water being the medium of preservation; life consists of three series—vegetables, vegetable-feeders, and animal-feeders,—it is surely not too much to suppose that the elimination of any one of these series, if such an event *could* arise, would materially affect the balance of the whole. In the absence of proof to the contrary, we may not unfairly assume the same principles and the same results in reference to artificial Aquaria. Although, so far as I am aware, there are no statistics of the mortality of fishes in public Aquaria, I have been informed by Mr. Edwards—and it is a very important fact in illustration—that grey mullet have thriven successfully in a private Aquarium for upwards of eleven years, and this may probably be due to the circumstance that vegetation of some kind is always found in such an Aquarium, thus affording natural food for the inhabitants.

Mr. Gosse's remarks on the growth of sea-weeds in Aquaria (*The Aquarium*, page 276) should be perused by all interested in this question, as also a Paper by my friend Mr. A. W. Wills, in which the writer strongly advocates the introduction of sea-weeds into the Aquarium.*

If sea-weeds are simply required as an ornament in addition to the *Ulva latissima*, none are so hardy and beautiful as *Bryopsis plumosa* and *Griffithsia setacea*, and if introduced attached to stones they will flourish artificially for many months, without exhibiting any signs of decay.

While on the subject of vegetation, I do not maintain that the autumn is the *only* time of the year when a Tank may be established. It certainly can be set up at any time, but, so far as my experience has shown, if established at any other period and without

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*** "Shall we have vegetation in Aquaria?"—A Paper read before the Birmingham Natural History and Microscopical Society, by A. W. Wills, F.C.S., President, 1875.**

the introduction of fronds of *Ulva latissima*, an inferior form of vegetation is most frequently the result. The silky greenish-black filamentous confervæ (*Spirulina* and *Oscillatoria*) spring up with marvellous rapidity in hot months, covering rockwork, glass, and shingle, and proving most difficult intruders to dislodge. In fact they cannot be thoroughly exterminated without a regular scouring process, involving much time and trouble. Mr. Lloyd says that conferva, like fire, "is a good servant but a bad master." Its growth may be checked by the absence of light, and by rubbing the sides of the Tank, and the glass front, with a spade-shaped cleanser, covered with folds of lamp-cotton, such as that given at Fig. 8.

As to natural aids for removing excessive vegetation, I am not much inclined to them on account of their erratic character, but Mr. Lloyd speaks most highly of that important and effective vegetable scavenger *Haliotis tuberculata* (the Ormer), and states that no scrubbing is needed where it is, and where the light is not in great excess. Mr. G. Sherriff Tye, who has had much experience in the management of the Marine Aquarium, recommends *Trochus umbilicatus*, *Littorina littorea*, and *Patella vulgata* as good scavengers for a *small* Tank, and thrive well where *Haliotis* could not be kept by reason of its large size.

If the suggestions I have enumerated have been carried out as to the establishment of the Aquarium, the water in the Tank will be brilliant and sparkling,—clear as crystal,—very different from stagnant water, such for instance, as that which has been recently boiled and cooled, or which has been allowed to stand in a tumbler or water bottle for a day or two, in the absence of light and vegetation. It will have *life* in it, so to speak.

And now we come to the consideration of a very important question—the introduction of the *inhabitants* of the Aquarium, which should be done after there is an established growth of vegetation evolving oxygen.

It is not possible to give very specific directions on this point —so much depends upon the size, position, and healthy state of a Tank. As a rule, however, the higher the organisation of the animal, the larger the space required for its maintenance—for instance, half-a-dozen or a dozen anemones, according to size, may be maintained in space which would only accommodate four of the smaller crustaceans, such as shore crabs and prawns, or *one* fish not more than four or five inches in length. But what would apply to a low temperature in the winter months, would not hold good in weather when without much warning, tropical heat suddenly sets in. Regard must also be had to the locomotive or stationary habits of the animals introduced—vagrants are more difficult to maintain than settlers.

A brief acquaintance with the principles of Zoology—as before stated—will do more to aid the student in the management of an Aquarium and the association of the various inhabitants of the Tank than anything, and will familiarize him with the kinds of animals that may be associated together with advantage.

As to *feeding.* All marine animals require food to be given them and if this is not attended to, they will not survive long or thrive in the Aquarium, however well regulated it may be as respects the mutual balance of animal and vegetable life. A well-managed Aquarium, with the water unchanged, fosters the reproduction of minute marine life, such as *Infusoria, Entomostraca,* &c., upon which all the inhabitants of a Tank will feed naturally, and some, such as tube-worms and pipe-fishes, exist solely on this nutriment. We do not know upon what the *Holothuriadæ* (sea-cucumbers), and other vermiform echinoderms feed, as sand is usually found in their stomachs. Such animals, however, as the sea-anemones, the star-fishes, the carnivorous mollusca, and most fishes require to be fed artificially. This may be performed not less than once, nor more than four times a week, according to the temperature, taking care that by a too abundant supply of food an excess of carbonic-acid gas is not given off by the animals, which excess is more likely to arise in the summer months.

For artificial food which should be varied, I recommend uncooked fresh fish, such as haddock, whiting, sole, or smelt—any fish in fact that contains but little oil or fatty matter. Oysters are good, but too expensive now-a-days. Give mussels but rarely, as they have an enervating tendency (if I may use such a term in reference to a radiate) and weaken the animals if eaten too frequently. Living and healthy shrimps form a most important article of diet for many fishes—such as the Wrasse—but they are difficult to procure inland. On an average twopence or threepence a week is quite sufficient to supply all the food that is necessary for an ordinary Aquarium, as a fragment can be cut off fish intended for one's dinner. All food should be freshly killed, and never given in a decomposing state. Butcher's meat, poultry, and cooked meat should be avoided. My friend Mr. S. Allport records a remarkable instance where he gave a piece of cooked fowl to a sea-anemone, which almost immediately died as from the effects of poison.

The food should be chopped into very small pieces, and one of the size of a No. 1 shot given with a pair of wooden forceps—which for convenience of handling may be smaller than those at Fig. 7—to an anemone, which when expanded is about the size of a silver threepenny piece, and so in proportion. Fish, crustaceans, star-fishes, etc., may have larger pieces in proportion to their size, but it is better that they should be small.

It is curious to observe in the lowly organised order of sea-anemones a certain amount of instinct or sympathetic intelligence. When one is fed, the others in an Aquarium, although closed at the time, will soon expand in anticipation of their morsel. Crustaceans and many fishes will, when domiciliated, readily come and take food from the hand, and I once had a tame mollusk, the dog-whelk, (*Nassa reticulata*) which exhibited this intelligence, and always appeared with his long cylindrical proboscis carried aloft and waving to and fro whenever there was any feeding going on.

It sometimes happens that the water in an Aquarium indicates by a milky appearance or slight smell that some unusual amount of decomposition is going on, frequently caused by supplying food to the animals. In such cases I have found that a small quantity of Condy's fluid largely diluted at once restores the water to its former brilliancy and purity by oxidation of the impurities. This remedy requires to be used with great caution, as an excessive supply is detrimental to the *vegetation.*

After feeding the good old proverb suggests *rest*—and I have but little more with which to trouble my hearers about the management of the Marine Aquarium.

One thing I must mention—and it is an operation perhaps, a little troublesome, involving time and patience—*cleansing.* Once in the year, in late autumn, the Aquarium should be dismantled, except of course the rockwork—its living contents carefully provided for in vessels (temporarily), and the whole thing—slate, glass, rockwork, and shingle, thoroughly scrubbed with a brush, and rinsed again and again with fresh-water, before the sea-water is returned to the Tank. It is rather a tiresome process, but the stimulus to the increased health of its inhabitants will be an ample repayment of the trouble—besides fresh vegetation succeeds better when the decayed remains of a previous year's growth have been removed, and the surface of the rockwork presents a more favourable nidus for the attachment of the spores from newly introduced plants.

A sponge dipped in fresh-water and passed now and then over the water line on the glass in the Tank, will prevent the incrustation of saline particles, etc., difficult to dislodge if left for a time. Persistently adherent vegetation may be removed by the application of dilute sulphuric acid,—taking care that it is applied carefully, and the rockwork or glass well washed afterwards.

Mr. Gosse once told me a good story of an elderly lady acquaintance of his who had a Marine Aquarium, and whose views of cleanliness in its management carried her so far as to call forth the remark that "there is nothing for it but soap and water once a week!" Mr. Lloyd informs me that "so carefully balanced are the light, temperature, and air, in relation to the vegetation, animals, and water," that the Tanks in the Crystal Palace Aquarium do not require to be cleansed; that the supply of oxygen by artificial means is in fact, so great,—to use Liebig's famous expression "eremacausis,"—as to *burn up* all decomposing matter, and I am aware that some

Aquariists do not attempt the operation of cleansing in private Tanks, but my own experience is decidedly in favour of its being done as I have suggested, once a year in the late autumn.

Here is a Schedule of the present contents of my own Tank holding about twelve gallons of sea-water:—

3 *Mugil capito* (Grey Mullet) 4 or 5 inches long.

3 *Crenilabrus rupestris* (the Goldsinny), about the same size.

1 *Blennius pholis* (Smooth Blenny).

1 „ *Montagui* (Montagu's Blenny).

2 *Palæmon serratus* (Common Prawn); and,

5 species (numbering 8 individuals) of Anemones.

Here is another Schedule from a glass Aquarium—a confectioner's cake glass, which I have previously described—holding between one and two gallons of water:—

2 *Syngnathus lumbriciformis* (Worm-pipe fish).

1 *Murænoides guttata* (Butter fish).

1 *Lepidogaster bimaculatus* (Two-spotted Sucker).

3 *Echinus miliaris* (Sea Urchin).

1 *Asterina gibbosa* (Starlet).

A mass of tube-worms (*Serpulæ*), numbering ten or a dozen.

Several tunicates, and 5 species (numbering 7 individuals) of Anemones. Microscopic life of all kinds is found, but of course I omit this. All the fishes in this Aquarium, it should be observed, are very small.

It is not too much to say that all these animals are maintained in as good health as it is possible to obtain within the limits of Aquaria of small size. Some of the radiates have been in my possession for years—two of them (*Tealia crassicornis* and *Anthea cereus*) are well known to Aquariists to be most difficult or almost impracticable to keep in health in a private tank. Some of the fishes (which include seven species) have been in captivity for eighteen months, and none less than four months, and they have grown appreciably. The blennies travelled by post from Cornwall last March in a tin box, packed with damp seaweed, and they have grown considerably since that time.

It must be always remembered by the Aquariist that it is not sufficient to keep his collection of animals in bare existence. *It would be cruel to do so.* They should present as nearly as possible the healthy appearance which they bear in their natural free state, possessing appetites to take the food offered to them, and performing the functions of reproduction—they will then be in a condition to be exhibited by the Aquariist with that satisfaction with which a horticulturist would show the treasures of a greenhouse, or the produce of a garden on which he has lavished care and attention.

It does not fall within the scope of the present Paper to discuss the construction of public Aquaria; besides, the subject has since the reading been carefully gone into by a Committee appointed by the Society.* The principles, however—before stated — which govern them and the management to which they are subject are of necessity the same, with few modifications, as those which apply to any Aquarium.

All honour to the Zoological Society of London, and to Mr. D. W. Mitchell, the late Secretary, and to Mr. E. W. H. Holdsworth for the establishment of "The Fish-house" or Aquarium in the Zoological Gardens in the year 1853, which was the first public Aquarium ever erected, and which still flourishes in nearly its original condition. Sufficient prominence as an independent institution, which it richly deserves, has however scarcely been given to this Aquarium. Its influence has, nevertheless, been very great, but it cannot, I think, be doubted that the remarkable biological and financial success that has attended the career of the Marine Aquarium in the Zoological Gardens at Hamburg, has mainly directed public attention to the important subject of Aquaria generally, and has stimulated commercial enterprise in establishing most if not all the public Aquaria that have been erected since. "The Hamburg Aquarium was opened in 1864, "and had the immense advantage of the early popularity of the re-"cently established gardens in which it is situated, and the still greater "one of being under the management of Mr. W. A. Lloyd, whose zeal "and self-sacrifice reduced the total current expenditure to £600 per "annum on a capital of £3,000. As a consequence, *capital and "profits balanced each other in six years.*"* The Directors of the Crystal Palace Company revived the example in England, and their Institution has, under Mr. Lloyd's superintendence, achieved extraordinary success. The Brighton Aquarium followed; and the munificent scale upon which it was projected, and the popularity it has enjoyed, are signs of its permanency. Marine Aquaria of importance have been opened at Manchester and Southport, and other are, I rejoice to hear, projected at Liverpool, Edinburgh, Glasgow, Dublin, Kingstown, Torquay, Plymouth, Hastings, and Scarborough, as well as in our own good Town; and I venture to look forward hopefully to the time when every large town in England will have its Marine and fresh-water Aquarium open to the mass of the people at a nominal charge.

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* Report of a Committee appointed by The Birmingham Natural History and Microscopical Society to obtain information respecting the subject of a Marine Aquarium, with the view of promoting an efficient Institution of the kind in Birmingham. 1874.

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* **Report of a Committee, &c. (previously referred to), page 9.**

It may be interesting to state, for the information of those who have not studied the question, that the Aquaria at Brighton and the Crystal Palace typify two entirely distinct systems.

At Brighton there is no means of circulating the water from tank to tank, and the water in the reservoir is small as compared with what is in the show tanks containing the animals. The water can, however, be renewed from the sea; but, in consequence of the supply-pipe being near the shore, sand and other detritus are mixed with the water, which requires some time to become clear. Aëration is effected by pumping air into the tanks through vulcanite pipes of *large* diameter, and purification is assisted by the presence of oysters and other mollusks in the tanks, as first suggested by Mr. Gosse.

In the Crystal Palace system there is a large reservoir four or five times the capacity of the show and store tanks, and by means of gravitation, and by force-pumps in duplicate to meet cases of accident, a perpetual circulation is effected. This is carried out by means of a pipe extending over the tops of the tanks, from which, under pressure of the force-pumps, a *small* jet of water, the pressure of which can be varied, is directed into each tank; and the jet of water in passing to the bottom of the tank carries with it innumerable small bubbles of air, so minute as to have the appearance of "falling sand" in the water, or dense steam seen in the air, and thus every portion of the tank is submitted to the most perfect oxidation. The result is that the water is always brilliantly clear, and the animals in the Aquarium enjoy health in as great a measure as can be obtained within the limits of this kind of artificial existence.

In the writer's judgment—without at all undervaluing the usefulness of the noble Institution at Brighton*—the circulating or "natural" system, as in operation at the Crystal Palace, appears to him to be immeasurably the most effective, and only lacks the complement of an indigenous growth of sea-weeds, not merely as an adjunct to aëration, but especially as a means of supplying some of the natural vegetable food for the animals (which under present circumstances they do not obtain), to make the system as near perfection as our present knowledge of these matters enable us to form a conclusion as to what is perfection in the management of the Aquarium. To put it plainer:—if the circulating system were in operation at Brighton, judging from the success of the Crystal Palace system, at least three times the number of animals might be maintained at Brighton as compared with the number now in the tanks.

But far above all other public Aquaria in the world in scientific importance, the highest rank must be assigned to the Marine Aquarium at Naples, and all Biologists owe a deep debt of gratitude to Dr. Anton Dohrn, the eminent founder, to whose ability, energy, and fortune its success is attributable. Constructed principally on the "natural" system as in operation at the Crystal Palace with some recent modifications to prevent loss of eggs and embyros by the passage of the water from one tank to another, the Aquarium from its proximity to the Mediterranean sea, exhibits a semi-tropical fauna, wonderful and beautiful; and to us dwelling in colder temperatures, perfectly unfamiliar. Not, however, is the Aquarium unique as a mere spectacle or public recreation, which it most certainly is of the highest eminence, but specially so as a scientific institution. *La Stazione Zoologica* in connection with the Aquarium, to which is attached a laboratory of twelve tables and a valuable library in many languages, where accomplished Naturalists from all parts of the world—under most liberal arrangements of the management—have facilities for pursuing the most abstruse studies into the structure, embryogeny, and development of marine invertebrate life.* May the noble example set by Dr. Dohrn find many imitators!

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* See an interesting Paper entitled "The Brighton Aquarium," by W. Saville Kent, F.L.S., in *Nature*, vol. viii. No. 208, 1873.

In these days when Sanitary Science deservedly occupies so large a share of public attention, and promises to influence the future condition of the people, the Sanitarian may take a lesson from the Marine Aquarium, for the principles which govern it—the mutual dependence of animal and vegetable life—are the principles which govern our existence: they are continually in operation within us and around us. The keeper of an Aquarium cannot be otherwise than a sanitarian, and to a certain extent a physiologist; for if he is to manage his Aquarium efficiently, he is bound to notice most particularly the elementary principles of Sanitary Science—namely, that the animals he has undertaken to maintain in an artificial state of existence can only be so maintained by preserving them in a cleanly habitation of sufficient cubic space, and by supplying them with pure air, pure water, pure and varied food, by maintaining as far as possible an uniform degree of temperature. The Aquariist will carry these principles into the management of his own dwelling, and they will influence his conduct whenever he is called upon to discharge analogous duties for the benefit of the community.

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* See an interesting account of the Marine Aquarium at Naples, by Professor E. Ray Lankester, in *The Athenæum*, 9th May, 1874.

Before concluding the subject, I feel bound to say, with reference to the management of the Marine Aquarium, that the points whereon I have imperfectly touched, are simply stated as the results of my own experience, and that I do not consider the conclusions arrived at, in any way dogmatical or final. We cannot too strongly bear in mind the quotation from Lord Macaulay which a former President* gave some time ago:—"It is philosophy which never rests, which has never "attained, which is never perfect. Its law is progress. A point "which yesterday was invisible, is its goal to-day, and will be its "starting point to-morrow." This aphorism eminently applies to the Marine Aquarium, as to every other branch of Natural History, and I shall feel much obliged to the Members of this Society, and to anyone who will kindly take the trouble to give me the benefit of his or her experience in the management of the Aquarium, and point out wherein I am wrong, and how I may improve. It may be probable that my experiments have been conducted on too small a scale, and that greater results would have been obtained, had larger resources been at my disposal. This I freely admit—with the reservation however, that I have been satisfied so far, and have not desired to incur further responsibilities. *Finis coronat opus.*

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* S. Allport, F.G.S. "President's Address," Birmingham Natural History and Microscopical Society, 1869.

My system—if I may venture without egotism to call it such—has been reduced to such automaton-like accuracy that whenever I have left home for a fortnight or three weeks in the autumn (generally a precarious time for the Aquarium on account of the variability of the temperature), I have been quite content to leave my Aquaria in charge of one of my boys (under twelve years), or in that of an intelligent domestic to whom I have just given a few plain instructions, and I never remember to have returned and been disappointed at finding that an accident had happened to the contents;—on the contrary, all has invariably gone well.

Wherever in this Paper I have differed from those whose judgment I value, I have expressed my own convictions, and I have stated the reasons on which they are based. I trust my friends will concede to me that freedom of opinion which they claim for themselves.

My Paper would perhaps be incomplete without some reference to the Marine Aquarium æsthetically and economically considered. A good Aquarium is an untiring and ever pleasing object of interest and study both to oneself and friends. Unlike a green-house or garden, its treasures are always the same—the animal flowers are ever blooming—and the graceful motions of the crustaceans and fishes may be watched for hours together. When supplemented by a Microscope a new and inexhaustible field of observation and enquiry opens up to the mind—because in a healthy Aquarium microscopic forms of life are constantly being developed from germs in the water, and many of the higher forms of marine life may be examined *in situ*. And what may be said of a private Aquarium, may be said of public Aquaria with far greater force. It cannot be doubted that a public Aquarium successfully managed is one of the greatest triumphs of science that has ever been applied to the furtherance of the study of Natural History. When one looks back over the history of the Aquarium and remembers its introduction as a fashionable amusement twenty or more years ago, when the genial artist John Leech satirised it in *Punch*, among the follies of the day, our times indeed have changed, now that *Nature*, the most influential of scientific serials, records the additions to the Brighton Aquarium as regularly as the *Morning Post* chronicles the movements of Society. No one who ever sees that wonderful collection, or the smaller, but (to me as a Naturalist) still more unique and beautiful one at the Crystal Palace, but comes away with his mind exalted by the contemplation of beings his remotest fancy never could have pictured in their living state; confined it is true, but free and active as in "the depths of the sea." To those who have not seen either, I say visit *both*. You will come away and wish you had such a collection in our good Town—and wishing may lead to action, and to helping on our movement to establish one.

I have elsewhere* expressed my opinion that a Marine Aquarium, if constructed properly and managed efficiently, would be most acceptable to Birmingham, and most appropriate, because this was the adopted town of the great Priestley, the discoverer of the principles that govern the Aquarium. It seems to me—and I know others whose judgment I value share my opinion—that no greater attraction or means of intellectual recreation for the working classes and our neighbours in the mining districts could be devised—because it would be so utterly different from any other exhibition now existing, and so suitable as a relief and mental refreshment for those in crowded courts to whom the *sea* is but a name! It is of no use denying the fact that "the Sea and its living wonders" have irresistible fascinations for us who live far away from them.

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* *Nature*, Vol. IX, page 264. January, 1874.

The Marine Aquarium appeals to the two extremes of society; to the unlettered—who look with wonder and curiosity on strangeness of form, and beauty of colour—and to the cultivated, who from a higher point regard with profound interest, details of structure and affinities and analogies with beings of other worlds and times besides our own. The Marine Aquarium is at once a living museum—a beautiful picture—a choice library! No cabinet collection of dried specimens can bring to view such instances, among a thousand others, as the graceful progress of the *Pleuronectidæ* (the flat fishes) or the weird form and muscular contractions of the cuttle-fish! No picture ever painted, can rival in colour the markings of the Wrasse, or the "living fire" (as Mr. Newman aptly terms it) of the eyes of the gemmeous Dragonet! No library on Zoology can give the Student a clear idea of the denizens of the deep from mere description, as can the contemplation of the actual living beings themselves. Doubtless as a utilitarian agency for the solution of undetermined points in Biology, the Aquarium is still in its infancy, though I cannot help thinking, that if the successful cultivation of some marine plants were combined with it, as I have shown it can be, even in a small Aquarium, it will be of immense value by supplying its inhabitants with vegetable food (which under present circumstances they do not obtain,) they may breed freely in confinement, and we may in some measure help to arrive at a solution of such problems, as how to secure the proper development and render available those almost innumerable germs of food supply, that are produced by sea fishes in general. For instance, the Turbot produces about fourteen millions of eggs annually, of which not one perhaps in ten thousand reaches maturity, nor one in a million finds its way to our tables! Our knowledge of the laws governing the movements—appearance and disappearance in certain localities—of the Herring and other fishes, their spawning and time of development, is still obscure, and if we had light upon this subject, thousands of tons of valuable food would be available for us of a most nutritious and palatable character. I cannot consider these enquiries visionary or the results obtained from them unprofitable, when I remember that within the last few years judicious legislation, the result of accurate knowledge obtained by these researches, has so developed the Salmon fishery, that in place of this fish being only obtainable by the few and wealthy, it is now every season so cheap and abundant as to be found on the table of the artizan. But this is not our present question, the Marine Aquarium as a public Institution is established for purposes of amusement and instruction. As mankind becomes more highly educated, higher intellectual recreation will not be a luxury but a necessity, and as such the public Aquarium eminently ranks in our days. May the time arrive when the proposed Marine Aquarium for Birmingham shall become an established fact, and that it may be on such a scale as to rival or even surpass those of other cities, either English or Continental, which already possess such a treasure is the very earnest wish of mine, shared, I believe, by most of the Members of this Society.

POSTSCRIPT.

VASCULUM FOR COLLECTING MARINE ANIMALS.

In the *Zoologist* for 1864, page 9,340, I described a newly devised *Vasculum* which I had in use for the collection and transmission of living marine animals from the coast. Since that time my friend, Mr. W. P. Marshall, has been good enough to take the subject in hand, and has much improved upon the original design, which after long experience was found to be somewhat too heavy, and otherwise objectionable in consequence of the chipping off of the enamel with which the Vasculum was coated. I think it not inappropriate to append a description of this Vasculum—as kindly supplied by Mr. Marshall—to the foregoing paper, as it may be exceedingly useful for those who collect personally, or who require their specimens to be forwarded direct from the sea coast. It may not be generally known that most marine animals do better when packed in damp sea-weed than when transmitted in sea-water. All the sea-anemones and corals, all the echinoderms, many crustaceans, and several littoral species of fishes may be packed in this way. Mr. Lloyd, in a very interesting Paper in the *Zoologist* for February, 1874, gave an elaborate account of the best modes of transmission of Aquarium animals, which may be read with advantage by all Aquariists.

The following is Mr. Marshall's description :—"Vasculum or collecting-can for aquatic objects, of light construction, convenient for "carrying, compact when open for use, quite plain and smooth, and "free from any recesses in which small objects might be lost, or dirt "accumulated, and readily made clean and dry after using.

"It consists of a square metal can (Fig. 9) with rounded corners, 6 "in. long, 4½ in. wide, and 6 in. high, with a flat lid having a perforated centre for ventilation; the lid is without any lip or fastening, "and has a projecting hinge that allows it to hang close against the side "of the can when open; and the can has a square shaped wire handle "that falls down close to either side, and has a wood handle threaded "upon the centre portion, the same length as the can.

"The bottom half of the can forms a well for carrying living "animal and vegetable objects in water, and the upper half is occupied "by a metal tray 3 in. deep, (Fig. 10) that fits the can loosely, and is "supported at each end by a narrow lip resting upon the top edge of "the can. This tray has a perforated bottom for drainage, and a vertical "tube ¾ in. diameter is fixed in the centre, having a funnel shaped top "1½ in. in diameter level with the top of the can; this gives access to "the well whilst the tray is in its place, and also serves as a ventilator "for the well, and a handle for lifting the tray." Animals not requiring to be transmitted in sea-water may be packed in damp sea-weed and placed on this tray, where they are kept from being crushed, and the medium in which they are packed is constantly preserved moist, by the dashing up of the sea-water in the well, which water can be frequently changed during a long journey without much difficulty.

The Vasculum has been very efficiently and economically made of copper by Mr. T. M. Walker, 17½ Lower Priory, and the Plating Company (Limited), 82 Lichfield Street, Birmingham, have successfully coated it with their patent nickel deposit, which protects the metal from any action of sea water, and preserves every part perfectly bright and clear as silver—an immense advantage, as many delicate marine animals succumb under the effects of confinement where oxidation is going on from water coming in contact with iron, tin, zinc, or indeed with any metal, so far as my experience goes,—except nickel, which seems to be absolutely impervious to the action of sea water.

LIST OF COLLECTORS, &c. OF MARINE ANIMALS.

As I have been frequently asked by friends and others, where and from whom they can obtain marine animals, I have thought it desirable to furnish the names of collectors of, and dealers in such animals.

If marine animals are wanted, it is best to order them in the late autumn or early spring months, because on account of the low tides prevailing, rarer and finer animals can be secured, and they will bear travelling far better when the temperature is low.

The following names of Collectors are principally taken from Mr. Lloyd's Handbook, referred to in my Paper.

Mr. E. Edwards, Vrondeg, Upton Park, Chester.
„ J. Holwell, Morthoe, Ilfracombe.
„ W. Jenkins, 2, St. Julian's Cottages, Tenby.
„ R. Pile, Swan Street, Torquay.
„ J. B. Randell, 19, Allez Street, Guernsey.
„ C. Rogers, 18, St. Andrew Street, Plymouth.
„ A. J. R. Sclater, Bank Street, Teignmouth.
„ R. J. Smith, 25, St. Alban's Row, Weymouth.
„ J. Thompson, 11, York Place, Southend, Essex.

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Fig 1

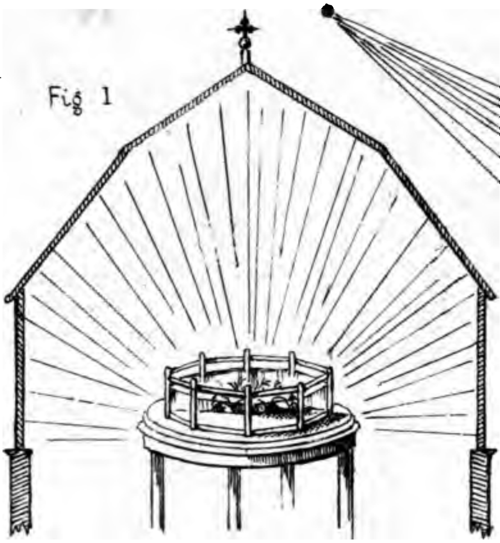
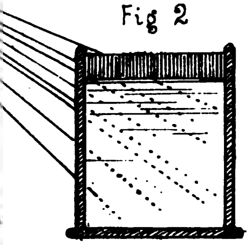


Fig 2



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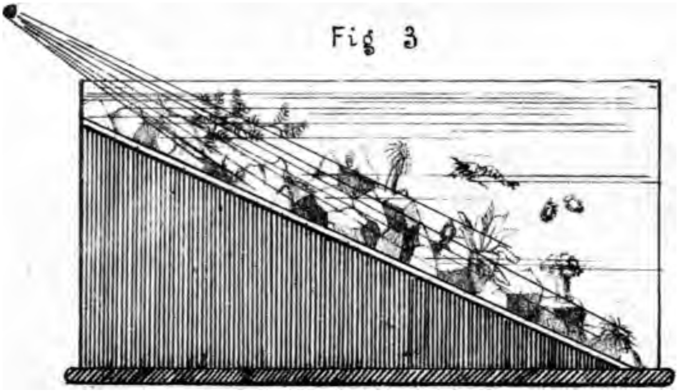

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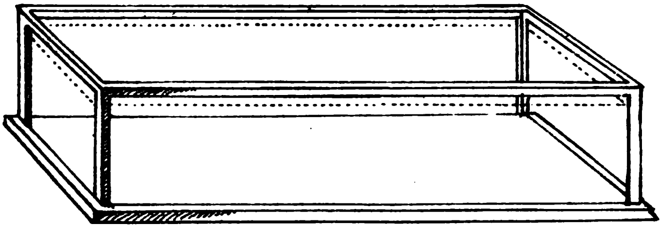

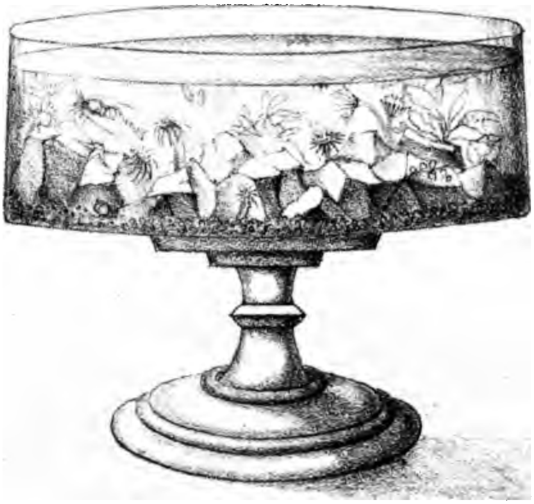

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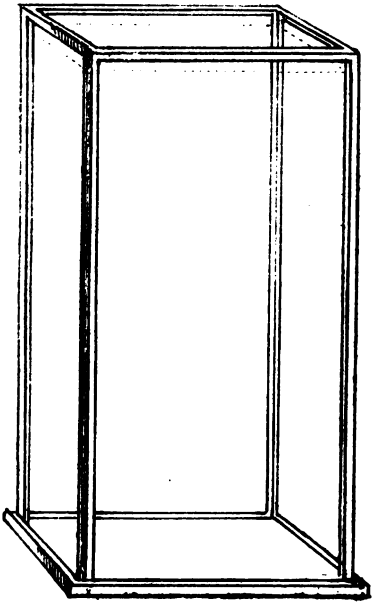

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Fig 7

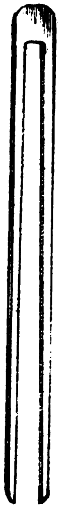
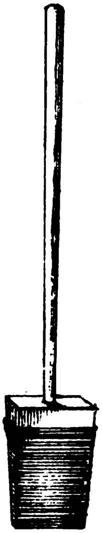


Fig 8



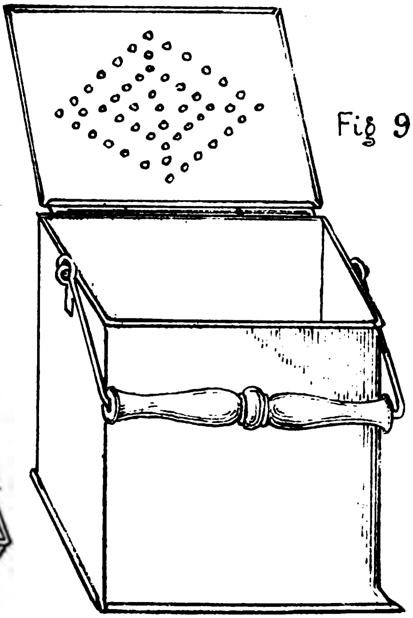
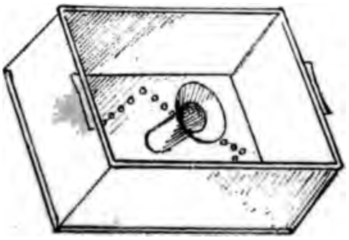


Fig 9

Fig 10



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